INCLINED GRID MOBILITY ANALYZER: THE PLAIN MODEL

H.Tammet

Hannes.Tammet@ut.ee

Department of Environmental Physics, University of Tartu,
18 Ülikooli Str., Tartu, 50090 Estonia

REFERENCES

Zeleny, J. (1898) On the ratio of velocities of the two ions produced in gases by Röngten radiation, and on some related phenomena. Philos. Mag. 46, 120–154.

Tammet, H. (1970). The aspiration method for the determination of atmospheric-ion spectra. IPST, Jerusalem.

Loscertales, I.G. (1998). Drift differential mobility analyzer. J. Aerosol Sci., 29, 1117−1139.

Tammet, H. (1999). The limits of air ion mobility resolution. Proc. 11th Int. Conf. Atmos. Electr., NASA, MSFC, Alabama, pp. 626–629.

ACKNOWLEDGEMENTS

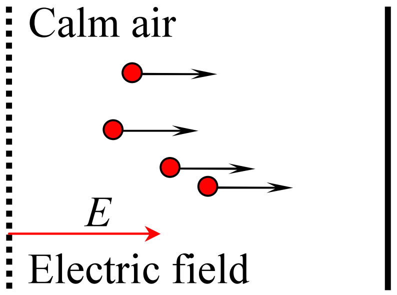
The author wishes to thank the Estonian Science Foundation (grant 4622) and Prof. P. H. McMurry, University of Minnesota, for supporting this work.

INTRODUCTION

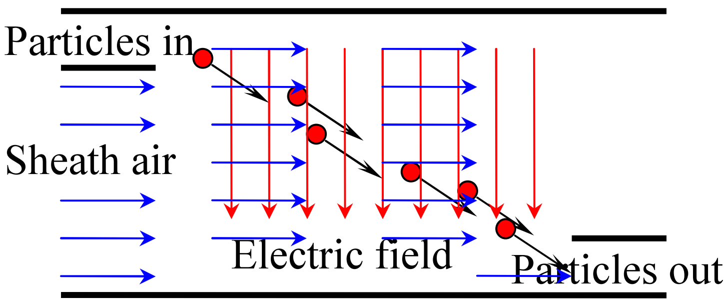
I have explained the idea of the method of inclined grids in Edinburgh 1998 in the oral presentation only, there is nothing about inclined grids in the printed abstract. Thus I should briefly repeat some information presented in Edinburgh.

Traditional methods:

Drift tube or time-of-flight method



Method of transversal velocities or classic aspiration method



Brownian limit of mobility resolution

$$\delta = \delta_\circ = \sqrt{2\frac{kT}{qV}}$$

Thermal energy

Electric work

Brownian limit of mobility resolution

$$\delta_d = \kappa\delta_\circ, \qquad \kappa > 1$$

Loscertales (1998) showed that the restriction **κ > 1** is specific for transversal velocities and **κ < 1** is possible, when the electric field is not transversal to the air flow, and the direction of electric component of the velocity is inclined opposite of the air flow velocity. Loscertales proposed to produce inclined electric field using non-equipotential electrodes.

The term "*method of transversal velocities*" introduced in the end of 19 century requires an alternative "*method of parallel velocities*". This is a well forgotten method by **Zeleny (1898),** the instrument is like the drift tube, but both electrodes are grids and the air is blown opposite to electric field. The cluster ions to be measured are generated inside of the instrument between the grids by X-rays. The resolution of the Zeleny instrument has been characterized by (Tammet, 1999):

$$\kappa = \sqrt{\frac{qV}{\underbrace{qV + qEut}_{\text{Electric work in air flow}}}}$$

Electric work in calm air

Residence time

Air flow velocity

The physical mechanism of the boost of resolution is the same as in the instrument by Loscertales. Thus we could say that Loscertales introduced the "***method of inclined velocities***".

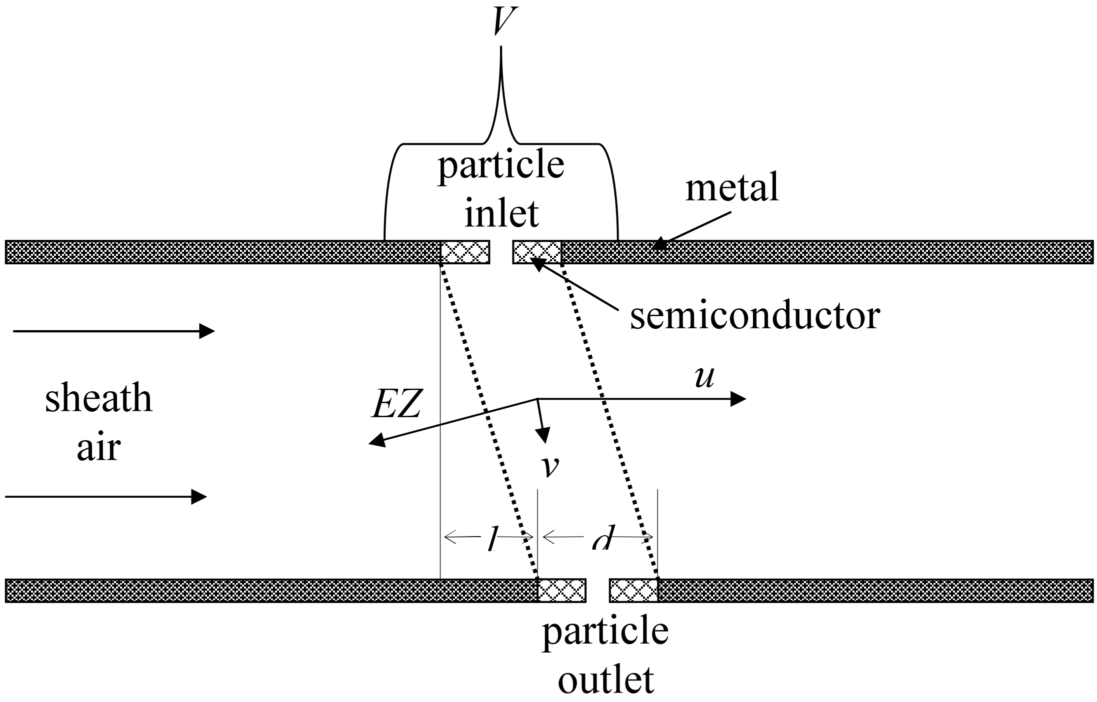
	Resolution	Continuous action	Particle outlet flow
Drift tube	standard	no	no
Transversal velocities	lower	yes	yes
Inclined velocities	higher	yes	yes
Parallel velocities	higher	yes	no

The method of inclined velocities seems to be most promising for cluster and nanometer particle high resolution measurements.

The problem is technical realization.

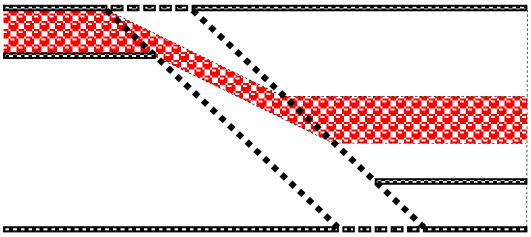
METHOD OF INCLINED GRIDS AND THE PLAIN IGMA

The inclined field can be accomplished by using inclined grids Tammet (1999). The picture shown in Edinburgh 1998:

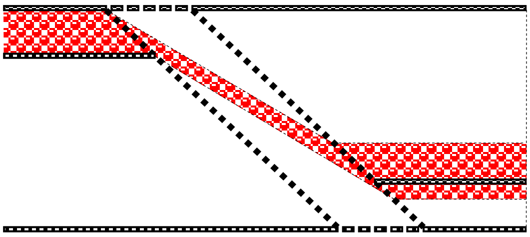


The above picture shows the idea but it is not good for technical realization. The simplest configuration of the Inclined Grid Mobility Analyzer (IGMA) that could be considered when planning a real instrument is the plain analyzer explained in next slides

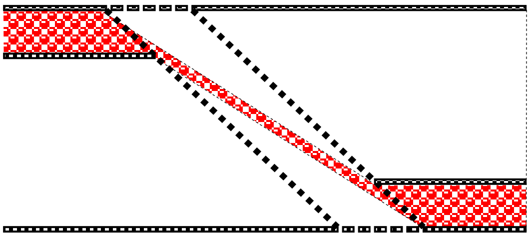
Monomobile charged particles passing a plain IGMA



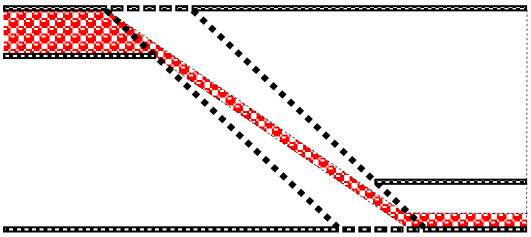
a) Voltage is too low or ions too slow.
No ions in outlet slit.



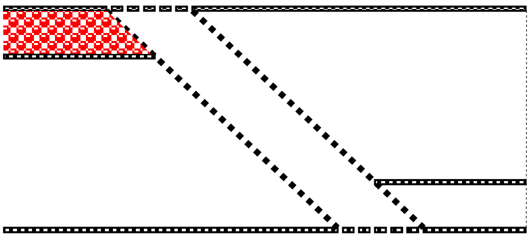
b) Voltage is low or ions are slow.
Part of ions in outlet slit.



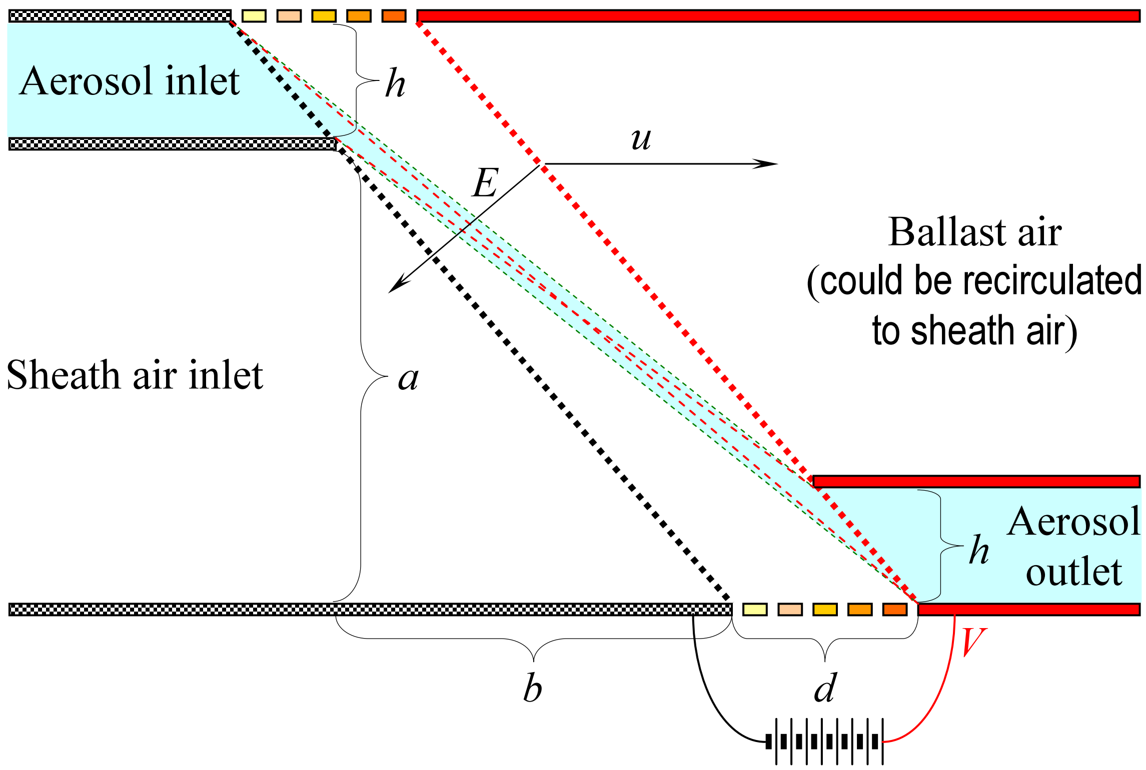
c) Ions are of central mobility.
All ions in outlet slit.



d) Voltage is high or ions are fast.
Part of ions in outlet slit.



e) Voltage is too high or ions too fast.
No ions in outlet slit.



DIFFUSION-FREE TRANSFER FUNCTION OF PLAIN IGMA

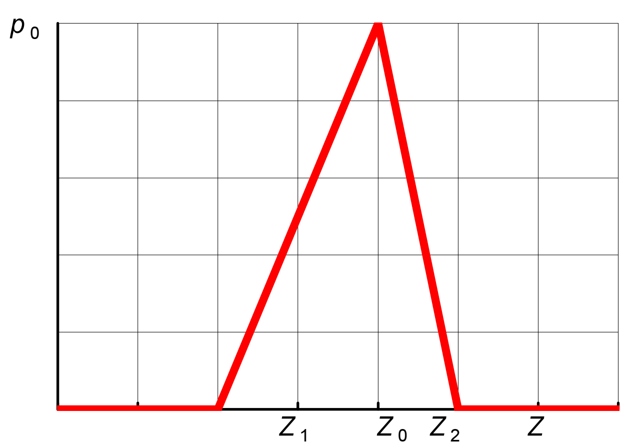
The trajectory calculations and the flux calculations (see Tammet, 1970) both are simple. Three critical mobilities are

$$Z_1 = \frac{ud}{V}\,\frac{1}{1+(b/a)\,(b+d-bh/a)/(a-h)},$$

$$Z_0 = \frac{ud}{V}\,\frac{1}{1+(b/a)(b+d)/a},$$

$$Z_2 = \frac{ud}{V}\,\frac{1}{1+(b/a)\,(b+d+bh/a)/(a+h)},$$

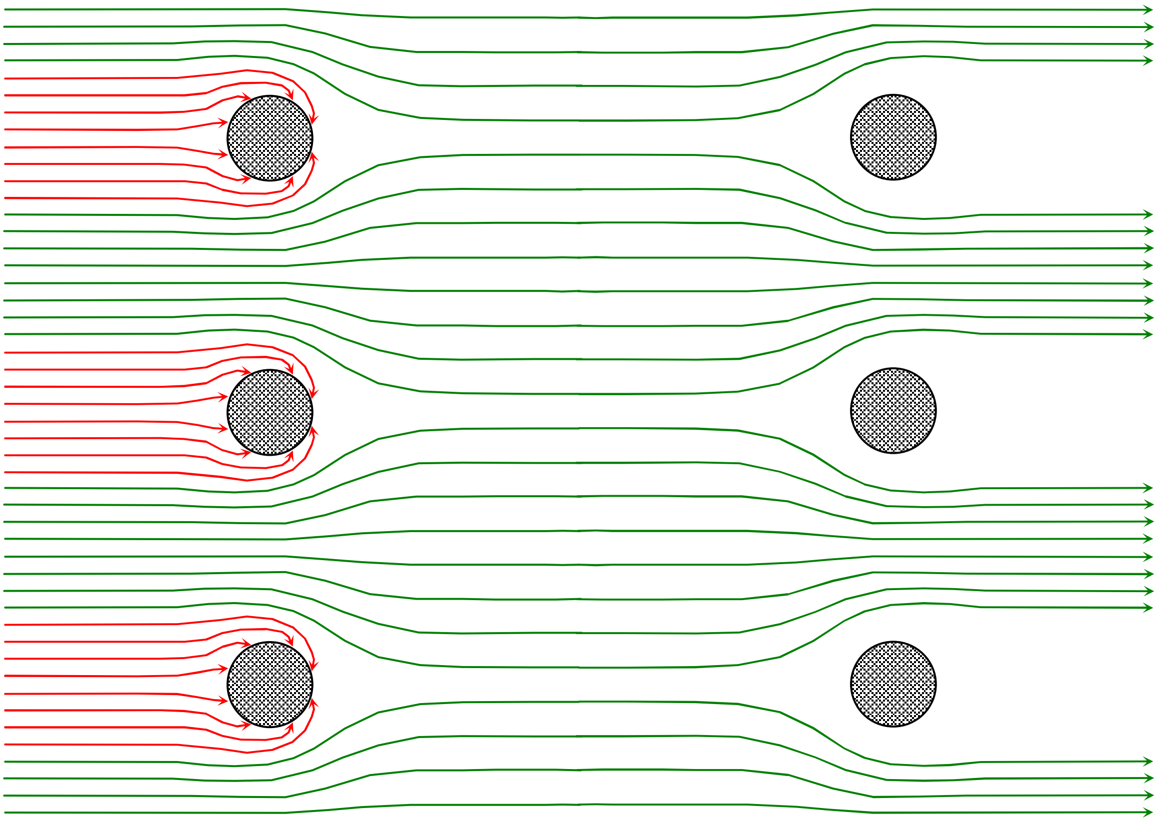
and the diagram of the transfer function looks as below:



Height of the diagram is:

$$p_0 = \frac{bd}{a^2+b^2+bd}.$$

Why $p_0 < 1$?

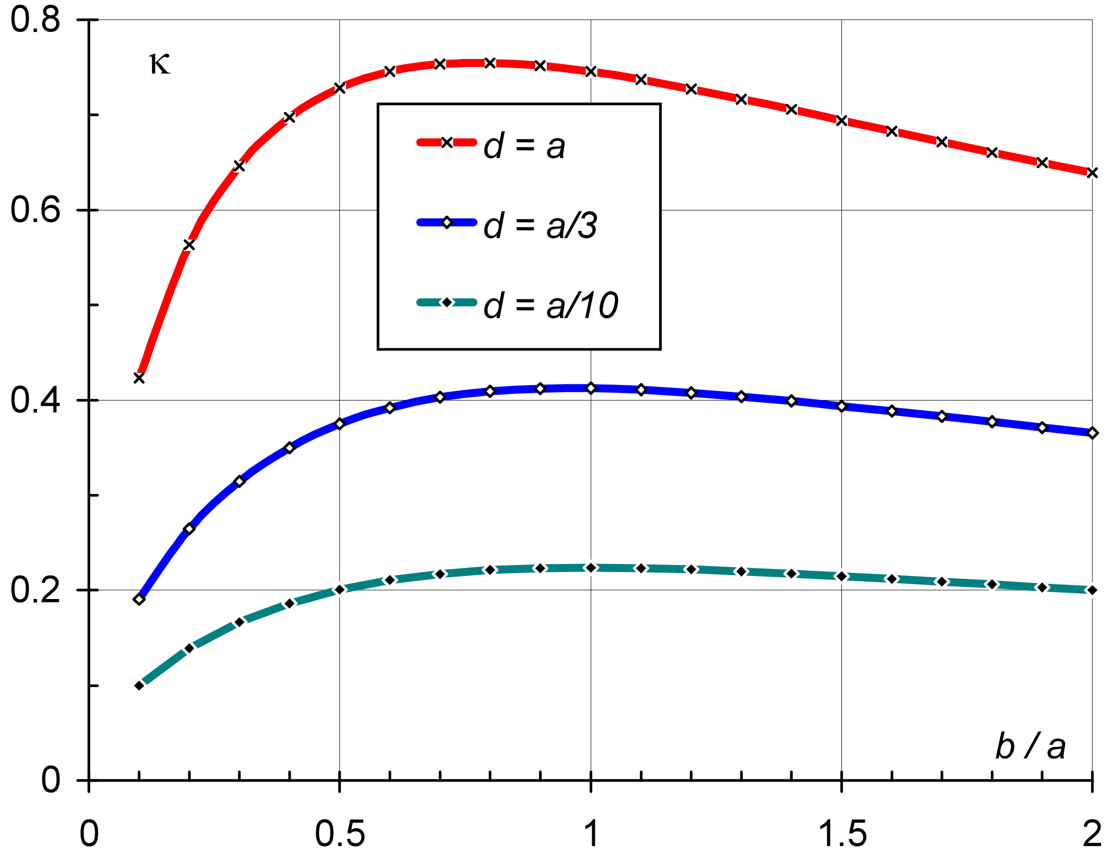


Particles are passing through two grids. First grid is attracting and second one is repelling the particles. Thus some particles are electrically lost on the first grid only. Diffusion losses are suppressed on the both grids, as the passing particles are electrically kept away of wire surface. The amount of lost particles is calculated using the method of fluxes and the result is as shown in previous slide.

EFFECT OF BROWNIAN DIFFUSION

The Brownian fluctuations of the trajectory are estimated according to the methods explained by Tammet (1970). Simple in principle but a technically troublesome calculation yields the result $\delta_d = \kappa\delta_\circ$, where

$$\kappa = \frac{\sqrt{1+\dfrac{d(b+d)}{a^2+b^2+bd}}}{\sqrt{1+\dfrac{a^2+b^2}{bd}}}$$



ADVANTAGES AND DISADVANTAGES OF PLAIN IGMA

Advantages:

- high mobility resolution,
- easy to keep plug air flow in the instrument,
- simple theoretical calculations,
- calculated transfer function could be trusted without comparative calibration.

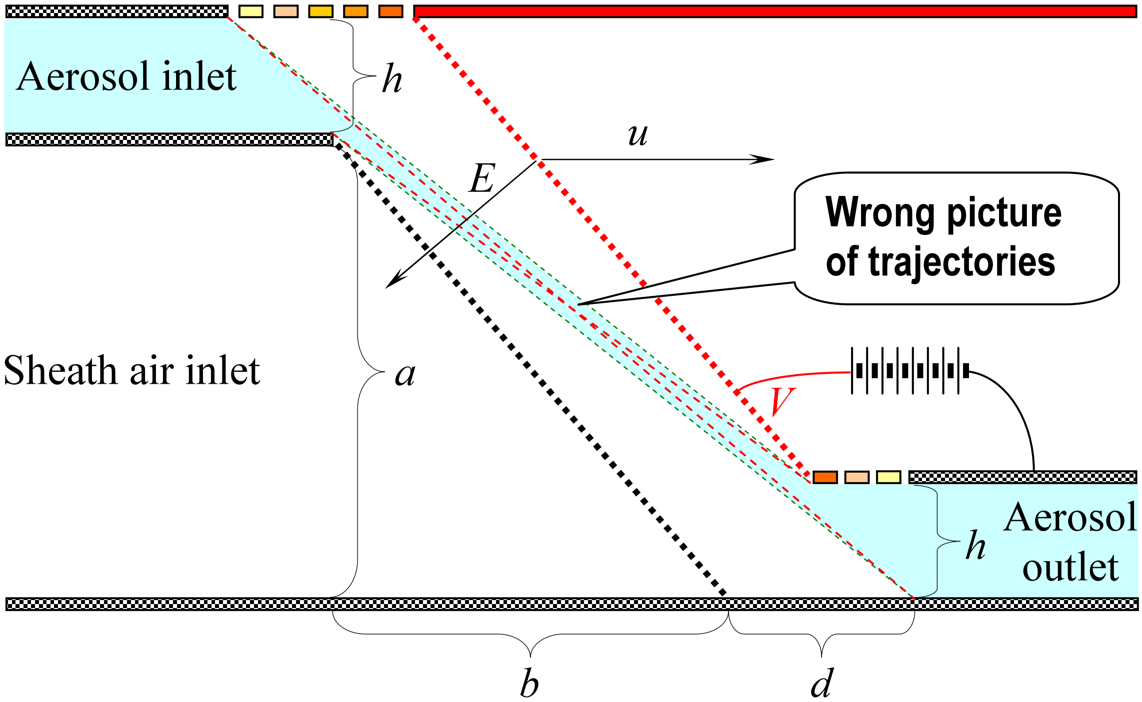
Disadvantages:

- one of the aerosol inlet or outlet is on high electric potential,
- loss on charged particles on attracting grid,
- driving voltage is not effectively used because the beam of monomobile particles does not fill the space between grids.

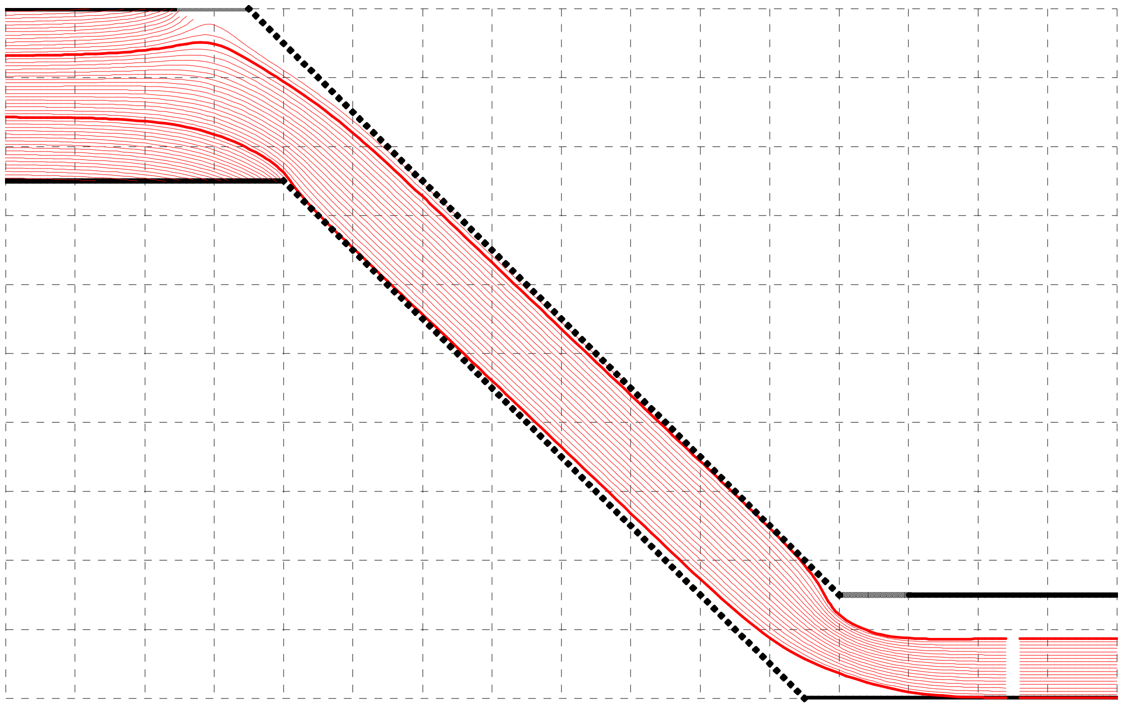
The advantages are most essential in analytic applications e.g. electrospray ionization mobility spectrometry, making this method competitive when compared with dominating method of electrospray ionization mass spectrometry.

The disadvantages are most essential in atmospheric applications where extreme mobility resolution is not required and the technical problems originate from the very low concentration of particles to be measured, typically less than 10 charged particles per ccm in the size range of 2-4 nm.

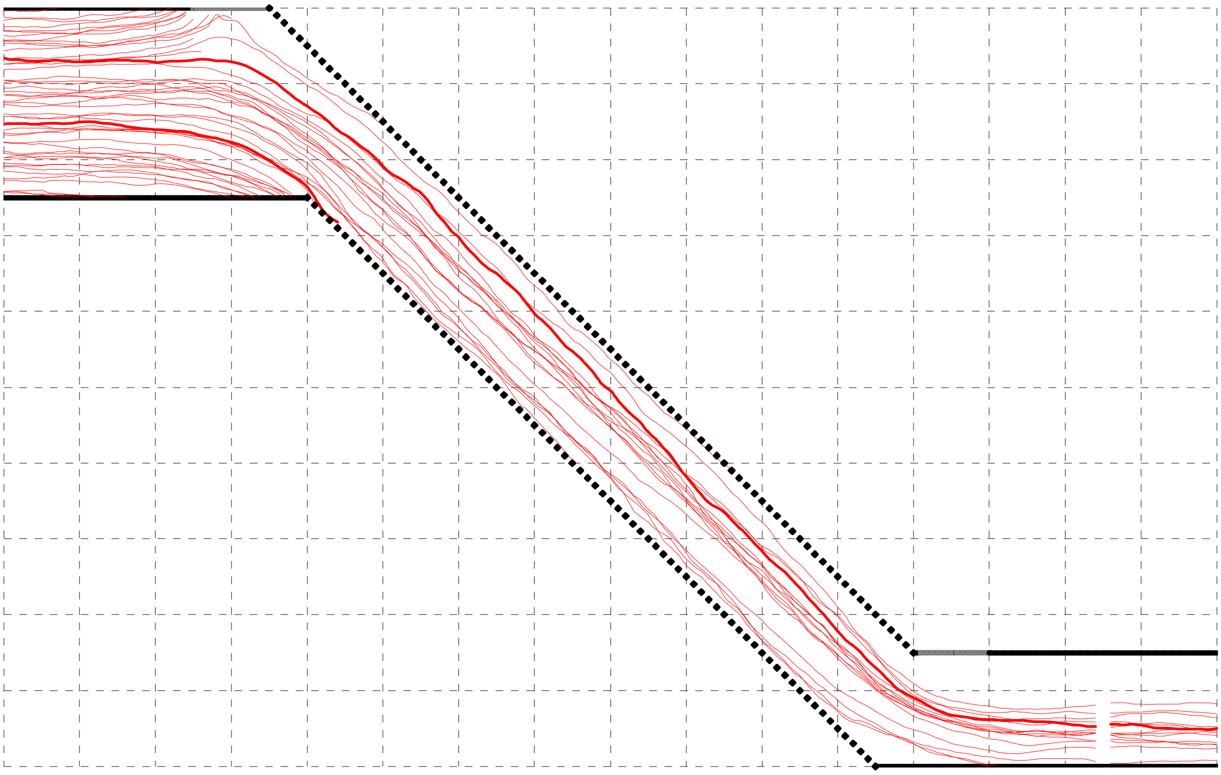
THE WAY AHEAD



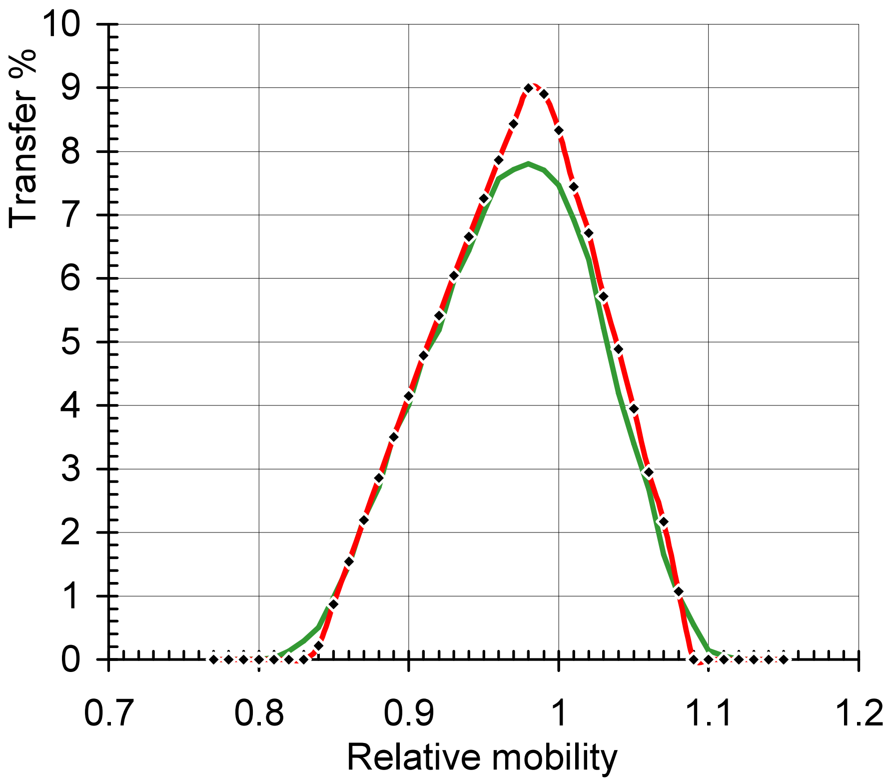
Calculated trajectories (plug laminar flow is expected).

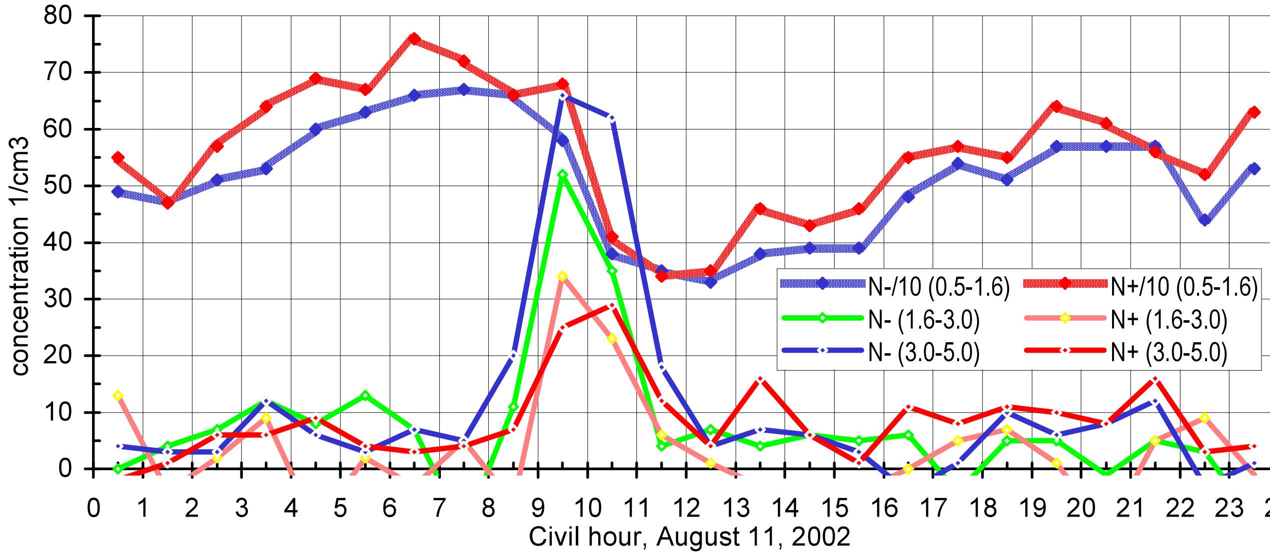


Turbulent flow, ε =10%



Transfer functions





Time series of charged cluster and charged fine nanometer particle size fractions, Atlanta experiment, August 11, 2002.